

## PATENT ABSTRACTS OF JAPAN

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(54) INVESTMENT CASTING PATTERN AND MANUFACTURE THEREOF

(57)Abstract:

**PROBLEM TO BE SOLVED:** To provide a manufacturing method of a shell mold for casting molten metal by forming a thermodegradable and low density thermosetting polyurethane foam pattern by reaction injection molding(RIM) having the same shape as the producing casting, in an investment casting pattern and a method thereof.

**SOLUTION:** In the thermosetting polyurethane foam pattern by reaction injection molding (RIM) having the same shape as the producing casting, the thermosetting polyurethane foam pattern by reaction injection molding having smooth continuous pattern surface as forming without forming a surface connecting open cell, in lower layer fine network structure of the pattern, is formed. Then, the shell mold is formed around this pattern and molten metal or molten alloy is cast into the mold manufactured by heating the shell mold and the pattern so as to selectively dewax the pattern from the shell mold without developing the shell mold cracking.

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]

[0001]

[Field of the Invention]This invention relates to molten metal, the investment casting pattern in which a melting alloy is cast, the transient model used especially for formation of a shell mold about that manufacturing method, and its manufacturing method in a shell mold.

[0002]

[Description of the Prior Art]In the "ROSUTO wax" method of common knowledge of investment casting, transience or a disposable wax pattern is made by carrying out injection molding of the wax dissolved into the die set by the shape of the parts to cast. Next, this fabricated wax pattern is made repeated and immersed into ceramic slurry, It is begun to pass the surplus slurry, and a shaping wax pattern is surrounded by investment in a ceramic shell mold by sprinkling with the ceramic particle or stucco of a coarse mesh until the ceramic shell mold of desired thickness carries out padding on this model. Next, by heating a shell mold and making a model usually eluted, remove a model from a raw shell mold and it leaves a ceramic shell mold, Next, this ceramic shell mold is calcinated at an elevated temperature, and the mold strength for which it was suitable when molten metal or a melting alloy was cast is given.

[0003]

[Problem(s) to be Solved by the Invention]By the way, in order to make a ceramic shell mold, when enforcing the "ROSUTO wax" method, the trial which forms a transient model by polystyrene foam or polyurethane foam has been performed. However, the model of polystyrene foam or polyurethane foam, it was not used by the fixed fault of the model which resembles the difficulty of removing a model from the shell mold surrounded by investment, without being accompanied by cracking of a shell mold, and is involved in model surface quality, model intensity, and the surroundings of a model in the extensive commercial production of "ROSUTO wax" casting. For example, invalidated United States patent 3rd 747

No. 663 showed that the model of polystyrene foam or polyurethane foam had the surface accompanied by an un-smooth open cell surface structure which is easy to damage. In order to solve this problem, before surrounding by investment in ceramic shell, said model is coated with separate work by thin-film-forming polymer at this patent.

[0004]

[Means for Solving the Problem]Then, it is a reaction-injection-molding thermosetting polyurethane foam model which has the shape as a cast to manufacture where it is the same in order that this invention may remove above-mentioned inconvenience, Said smooth reaction-injection-molding thermosetting polyurethane foam model which does not have a surface connection open cell in lower layer minute network structure of said model and which \*\*\*\*\* and has the model surface is formed, \*\* which forms a shell mold in the surroundings of said model, and is not accompanied by shell mold cracking -- said model -- from said shell mold -- alternative -- wax -- molten metal or a melting alloy which comprises heating said shell mold and said model so that omission may be carried out is cast

[0005]

[Embodiment of the Invention]In addition to the process of the shell mold by a reaction-injection-molding polyurethane foam model, this invention also provides the mold/model formed in this way, and a model, It is blended so that it may have the model surface and model intensity which make the model which there is no necessity of coating a model with a surface thin film or a layer, and makes a shell mold from the principle of the "ROSUTO wax" method a thing suitable for cast extensive commercial production, and the other features.

[0006]

[Example]Below, the example of this invention is described.

[0007]This invention provides the method of making the shell mold which performs extensive commercial production of the cast of metal and an alloy from the principle of the "ROSUTO wax" method. Although especially this invention is useful also to investment casting with exact parts of titanium and a titanium alloy in addition to the exact investment casting of the superalloy parts of nickel, such as a braid of the gas turbine engine which has complicated aerofoil shape, and a blade, and cobalt, However, this invention cannot be limited to this point and can be carried out to casting of arbitrary metal or an alloy.

[0008]The illustration example of the process of this invention includes forming the reaction-injection-molding thermosetting polyurethane foam model which has the same shape as the cast or parts to manufacture. This model mixes a polyhydric alcohol stream and an isocyanate stream, and forms them by the step reaction injection molding (RIM) introduced into the injection mold which has the die cavity which carried out shaping so that it might correspond to desired model shape.

[0009]While said model is made from self skinning RIM thermosetting rigidity polyurethane

foam (contrastive with the polyurethane foam of an elastomer), the important section of a die with this complicated RIM polyurethane firm -- a duplicate -- every about 10 pounds from which stiffness to the extent that it can surround by investment in a shell mold, without damaging a model or a mold, or rigidity is obtained -- every cubic feet thru/or 15 pounds -- the total model density of cubic feet within the limits. furthermore -- desirable -- every 12 pounds -- cubic feet -- or with the total model density of cubic feet within the limits the whole 15 pounds. smooth continuation one which there is no surface connection open cell, and has the cell size which are about 0.005 inch thru/or 0.010 inch and which covers the internal model minute reticulated core structure of low density comparatively is comparatively high-density -- it \*\*\*\*\* (ing) and with outside model epidermis or the surface. ash-free wax from the stability of the size covering each temperature requirement, and the shell mold which formed the shell mold on said model without carrying out a crack -- it is blended so that it may have the removal nature by omission. Said total model density is the density of a perfect model including said smooth continuation \*\*\*\*\* outside model epidermis or the surface, and lower layer minute netted inner core structure. There is no harmful or excessive organic metal catalyst which must not exist in casting of aerospace superalloy, such as a nickel base superalloy and a cobalt base superalloy, in said model substantially.

[0010] For example, said RIM rigidity polyurethane foam model, By step reaction-injection-molding (RIM) work, form using a prepolymer isocyanate stream and a polyhydric alcohol stream, and said polyhydric alcohol stream, While the selected additive agents, such as a catalyst which controls gelling and bridge construction, a water blowing agent, and a surface-active agent, are included, said additive agent, It collaborates whole about 10 pounds that cubic feet thru/or the feature of a model mentioned above in addition to this whole about 15 pounds with the shaping total model foam density of cubic feet, and smooth outside model epidermis or surface should be generated.

[0011] In the specific suitable example of this invention, a polyurethane foam compound, By the weight ratio (pbw) of this compound, the amount polyether polyhydric alcohol of polymers of the quantity of about 20 pbw(s) thru/or about 50 pbw(s), Low-molecular-weight polyether polyhydric alcohol of the quantity of about 50 pbw(s) thru/or about 80 pbw(s), The diamine epidermination additive agent of the quantity of about 5 pbw(s) thru/or about 15 pbw(s) which make easy to generate the smooth continuation model surface without a crack, The chain IKUSU tender of the quantity of about 2.5 pbw(s) thru/or about 10 pbw(s), The water blowing agent of the quantity of about 1 pbw thru/or about 4 pbw(s), and the non-silicone surface-active agent of the quantity of about 1 pbw thru/or about 4 pbw(s), each which controls a blowing reaction -- with the amine catalyst of the quantity of the tertiary-amine catalyst of the quantity of about 0.1 pbw(s) thru/or about 1.0 pbw(s), about 0.05 pbw(s), or about 0.2 pbw(s). Bridging and the gelling catalyst of the quantity of about 0.015 pbw(s) thru/or about 0.075 pbw(s),

diisocyanate of the quantity of about 79.23 pbw(s) thru/or about 190.96 pbw(s), and \*\*\*\*\*.  
The isocyanate index can become about 102 thru/or about 105 within the limits. An isocyanate index is common knowledge and equal 100 times of the ratio of the isolation isocyanate group versus isocyanate reactivity group (hydroxyl, amine, water) before a reaction occurs. The isocyanate indexes of 100 are hydroxyl, amine hydrogen, and a number with the equivalent of an isocyanate exact as a total of the equivalent of water. The isocyanate index of 104 as used in the following compounds means carrying out the multiplication of an isocyanate reactivity group's total (the number of the equivalents) by 1.04.

[0012]The illustration polyurethane compound of reaction injection molding consists of weight ratios (pbw) of this compound as follows. that is, compound pbw chemical property 1 polyether polyhydric alcohol 30 OH#=25, F= 3, and MW=6730 2 polyether polyhydric alcohol 63 OH#=360, F= 4.5, and MW=725 3 polyoxypropylene diamine . 7 MW=4004 chain IKUSU tender . 7.5 MW=62 ethylene glycol . 5) water 2 Six surface-active agents 1.5 -- non-silicon . 7) Tertiary-amine catalyst 0.18 amine catalysts 0.053 9 organicity tin catalyst 0.018 10 diphenylmethane diisocyanate 130.6 NOC%=29.5, F= 2.25, and MW=320 Isocyanate index 104[0013]Here, it is the number of OH#= hydroxyl and they are F= functionality, MW= molecular weight, and the percent of a NCO%= activity NCO end group.

[0014]A polyhydric alcohol component (1) can be obtained as Placo Lu 973 (Pluracol-973) liquid polyhydric alcohol from BASF Corporation (BASF Corporation). A polyhydric alcohol component (2) can be obtained as Bora Knoll 240-360 (Voranol-240-360) liquid polyhydric alcohol from a DEYU chemical company (Dow Chemical Company). An diamine epidermination additive agent (3) can be obtained as Jeffamine D-400 (JeffamineD-400) additive agent from Huntsman Petrochemical Corporation (Huntsman PetrochemicalCorporation). This ingredient really [ smooth / continuation ] which does not have a surface connection open cell in inside model of lower layer minute reticulated core structure promotes formation of outside model epidermis or the surface. The chain IKUSU tender ingredient (4) of ethylene glycol can be obtained from the Kern Central corporation (Chem Central Corporation). This ingredient promotes the hard segment density in a model, and generates comparatively strong or hard foam structure (comparatively high modulus of rupture). Water is one parameter which exists as a foaming agent which controls the free rise density of a form model, and controls model density. A non-silicon surface-active agent can be obtained as LK-221 surface-active agent from Air Product And Chemicals ink (Air Products and Chemicals, Inc.). This surface-active agent has comparatively low surface tension, and while polyurethane foams, it can support prudence. A tertiary-amine catalyst is OSI product SUPESHA Litaize ink (.). [ OSI Product Specialties and ] It can obtain as NIAKKUSU A-1 (Niax A-1) from Inc., and start promotion of the blowing reaction is carried out, and blowing to a gelling reaction is performed in a proper order. An amine catalyst is Air Product And Chemicals

ink ( ). [ Air Products and Chemicals and ] It can obtain as Dabco 8154 (Dabco-8154) catalyst from Inc., and start promotion of the blowing reaction is carried out similarly, and blowing to a gelling reaction is performed in a proper order. An organic tin catalyst is Air Product And Chemicals ink ( ). [ Air Products and Chemicals and ] It can obtain as T-Dabco 12 (Dabco T-12) catalyst from Inc., and it serves to control a gel reaction (bridging), synchronizing with a blowing reaction, and proper shaping is performed. Diphenylmethane diisocyanate of a fluid can be obtained as RAPURINETO MM-103 (Luprinato MM-103) from BASF Corporation (BASF Corporation). Since the above-mentioned catalyst except Dabco T-12 (Dabco T-12) is a mere organism, there is no harmful organic metal catalyst which must not exist in casting of aerospace superalloy, such as superalloy of a nickel base or a cobalt base, in said model substantially. Although T-Dabco 12 (Dabco T-12) catalyst contains tin, since it exists in the quantity of very few compounds, it considers that the level of tin is not worth serious consideration in a minute amount.

[0015] Usually, the polyhydric alcohol stream of the fluid which comprises an ingredient (1) thru/or an ingredient (9), The prepolymer isocyanate stream of the fluid which comprises an ingredient (10), The usual metal which forms the cavity which mixed in the recycle mix head of the usual RIM opportunity, and carried out shaping according to desired model shape. (For example, aluminum or tool steel) In a mold, to said mix head, with the injection pressure of 1000 psi thru/or 2500 psi within the limits. And optimum dose of materials are introduced by the flow of 100 g/s thru/or 400 g to a RIM mold cavity that metering should usually be carried out in about 2 seconds thru/or 4 seconds into a RIM mold cavity. Since the surface finish of a RIM mold is really [ of a polyurethane foam model / outside ] precisely reproduced by epidermis or the surface, RIM mold surface finish can be chosen so that it may give the casting eventually solidified in a shell mold and this shell mold, so that desired finishing may be given to a model outside skin or the surface therefore. Therefore, the surface finish of a RIM mold can be fitted to the surface finish of a request of the casting made in a shell mold.

[0016] Usually, since the parting line of the RIM mold is formed on the surface of the model therefore, it is making the casting estrange from a critical table side. For example, in the case of an aerofoil-like model, without passing along the concave surface or convex of an aerofoil, rather, the parting line of a RIM mold can pass along the trailing edge of the aerofoil which can remove a casting fin, before surrounding a model by investment in a shell mold. A RIM mold can be made from the steel which is known conventionally, aluminum, or other materials while it is suitable for this purpose. High-tech engineering ink ( ) [ Hi-Tech Engineering and ] The RIM opportunity which has each half of the mold heated / cooled in activity while being able to obtain as model PS-30 from Inc., It can be used in order to mix a polyhydric alcohol stream and a prepolymer isocyanate stream that desired model shape should be formed and to carry out reaction injection molding of the model compound. This RIM opportunity contains an air

new creator, in order to control the size of a cell, and homogeneity. A RIM mold is maintained at 120 Fahrenheit thru/or the temperature within the limits of 180 degrees during ejection and shaping of a model. Usually, release agents, such as the par film (Parfilm) etc. of the urethane which can be obtained from a price Driscoll corporation (Price-Driscoll Corporation), are applied on the surface of an injection mold in front of shaping of a model. The total cycle time after ejection of a common model is within the limits of 3 minutes thru/or 5 minutes.

[0017]Next, this fabricated polyurethane foam model opens each half of a mold, and removes it from a RIM mold by removing a model manually or calculating automatically by knock out pin. After removing this model from a RIM mold, it is made to cool to a room temperature and it does room temperature shell molding investment work for the first time after that.

[0018]Usually, this fabricated model does not have the necessity of washing before and after shell mold investment work. The usual model detergent which may contain dilution mineral alcohol by request that dilution citrate is included for a model in an aqueous solvent \*\*\*\* or in a solvent can wash. As it \*\*\*\*\* and the model surface was mentioned above, they are really [ smooth / continuation ] which \*\*\*\*\* and does not have a surface connection open cell of inside model of lower layer minute reticulated core structure in a model state outside model epidermis or the surface. Usually, epidermis or the surface does not really [ of this fabricated model / outside ] limit this invention to the value of the specific skin depth, although thickness is 0.002 inch thru/or 0.005 inch.

[0019]Next, the fabricated RIM polyurethane foam model is made repeated and immersed into ceramic slurry or a fireproof slurry according to the principle of the well-known "ROSUTO wax" method, It is begun to pass the surplus slurry, This shaping RIM polyurethane foam model is surrounded by investment in a ceramic shell mold or a fireproof shell mold by sprinkling with the ceramic particle, the fireproof particles, or stucco of a coarse mesh until the shell mold of desired thickness carries out padding on this model. By early ceramic slurry or fireproof slurry, and stucco, when casting melting superalloy to a mold, the face coat of the shell mold in contact with this melting superalloy forms. This face coat comprises the layer of two or more slurry/stucco. This shell mold face coat is supported or supported by two or more backup layers. The face coat and backup layer of the shell mold which casts nickel superalloy and cobalt superalloy are common knowledge.

for example, United States patent 5th with which the contents of instruction are included by quotation here -- 335 717 No. and United States patent 5th -- it has described to 297 615 No. United States patent 4th with which, as for the mold face coat and backup layer of the shell mold which casts titanium and a titanium alloy, the contents of instruction are included by quotation here It has described to No. 703806. The specific face coat and backup layer which were chosen in order to form this shell mold do not constitute a part of this invention. In the person skilled in the art, it could recognize correctly that the face coat and backup layer of a

shell mold may vary with the molten metal or the melting alloy cast in a mold as mentioned above.

[0020]making the shell mold in which a model is inherent usually heat in oven, a furnace, or other heating apparatus, after forming a shell mold according to desired raw (un-calcinating) shell mold wall thickness -- a model -- from a raw shell mold -- alternative -- wax -- omission is carried out. the \*\* to which the assembly of this shell mold/model does not carry out cracking of the raw shell mold -- a RIM polyurethane foam model -- alternative -- wax -- in order to carry out omission, it can heat 800 Fahrenheit thru/or within the limits of 1600 degrees in the air. If it begins to soften in about 450 Fahrenheit and also this model is heated, it will collapse. the \*\* to which thermosetting polyurethane foam does not carry out the phase change of this model to a fluid -- wax -- omission is carried out and cracking of the raw shell mold is not carried out -- it is making. the ashes in which this model remained in the advantageous thing into the shell mold by model decomposition -- substantial -- the state of zero -- wax -- omission can be carried out. Therefore, this invention has the function for it to be easily ash-free and to remove a model from a raw shell mold without carrying out cracking of the shell mold. as indicated, for example to the following examples, before \*\*\*\*\* omission work, it can be come out of the raw shell mold in which a model is inherent with the pressure of a high gas (for example, air), and high temperature, and it can perform direction gas pressure processings, such as an option. After model removal, although a shell mold is preheated or calcinated at an elevated temperature, this high temperature is usually fitted to the specific ceramics or refractories used in order to manufacture a mold, in order to give the shell mold intensity for which it was suitable when molten metal or a melting alloy was cast in a mold. The parameter of calcination of the shell mold which casts the superalloy of a nickel base or a cobalt base is indicated to the patent of the above-mentioned quotation included by quotation here.

[0021]an example -- although the following example is explained for the purpose of illustration, it is not limited to this. It fabricated in the RIM mold of the steel which carried out the electron discharge method (EDM) and ground the RIM polyurethane foam model of the above-mentioned compound so that it might have the shape of a turbogenerator wheel. this model came out with the following RIM parameter, i.e., the mixed pressure of 2000 psi, the flow of 200 g/s, the shot time for 0.2 second, mold temperature with Fahrenheit 120, and the release agent that comprises the par film (Parfilm) mentioned above, and was made. This fabricated model the total density of cubic feet, and really [ smooth ] without the crack superposed on the minute reticulated core had an outside skin or the surface whole about 15 pounds. It is the technique (that is, it is repeatedly immersed into ceramic slurry and) of the "ROSUTO wax" method about this model. beginning to pass a slurry -- stucco -- sprinkling -- it surrounds by investment as it is, without washing in a ceramic shell mold, and was made for a shell mold to have a cobalt aluminate nucleation face coat, and alumina and the backup layer which



comprises zircon The raw shell mold had the wall thickness of 0.5 inch of the maximum abbreviation. Direction gas (for example, air) pressures, such as 500 psi, were given to the raw shell mold which is inherent in a model for 30 minutes by 400 Fahrenheit. next, the ashes which exist in a shell mold -- the state of zero -- and -- without it carries out cracking of the raw shell mold -- a model -- wax -- in order to carry out omission, this mold/model were heated for 60 minutes to 1600 Fahrenheit in the air in a box furnace. Next, in order to prepare casting of a melting nickel base superalloy, the raw shell mold was preheated by a maximum of 2200-degree Fahrenheit for 3 hours. Next, in order to form one or more casts which have the shape of the transient model used in order to make a shell mold, teeming of molten metal or the melting alloy can be carried out to this calcinated shell mold by the usual cast technique. It has indicated carrying out teeming of the superalloy or the titanium alloy of a nickel base or a cobalt base to a shell mold to the patent of said quotation included by quotation here.

[0022]Especially when the shell mold manufactured in this way by the polyurethane foam model and this model casts the nickel base which has complicated or simple aerofoil shape, the gas-turbine-engine braid of a cobalt base superalloy or a blade, and the metal of titanium and the parts of an alloy, it is useful. According to a specific use, the casting of an aerofoil can be cast so that it may have the microstructure of a homaxial columnar crystal or a single crystal. However, this invention is not limited to a specific casting technique, the specific metal cast, or an alloy.

[0023]Namely, in this example, in addition to the process of the shell mold by a reaction-injection-molding polyurethane foam model, also provide the mold/model formed in this way, and said model, It is blended so that it may have the model surface and model intensity which make the model which there is no necessity of coating a model with a surface thin film or a layer, and makes a shell mold from the principle of the "ROSUTO wax" method a thing suitable for cast extensive commercial production, and the other features.

[0024]This invention provides the process of the shell mold which casts molten metal or a melting alloy by forming the reaction-injection-molding (RIM) thermosetting polyurethane foam model of low density by the heat collapsibility which has the same shape as the casting to manufacture. the important section of a die with said complicated model -- a duplicate -- every about 10 pounds from which stiffness to the extent that it can surround by investment in a shell mold, without damaging said model, or rigidity is obtained -- cubic feet -- or with the total model density of cubic feet within the limits the whole 15 pounds. The smooth continuation \*\*\*\*\* outside model epidermis or surface which does not have a surface connection open cell in inside of lower layer model minute reticulated core structure, ash-free wax from the stability of the size covering each temperature requirement, and said shell mold which formed the shell mold on said model without carrying out a crack -- it is desirable to be blended so that it may have the removal nature by omission. There is no organic metal catalyst which must not exist

in casting of aerospace superalloy, such as superalloy of nickel \*\* and a cobalt base, in said model. Next, said model is surrounded by investment in a ceramic shell mold or a fireproof shell mold, and the thin film of interface polymer or others is unnecessary on said model. [0025] In the example of this invention, said RIM polyurethane foam model, It forms by step reaction-injection-molding work using the prepolymer isocyanate stream which forms polyurethane foam into the injection mold which has the die cavity which carried out shaping to the polyhydric alcohol stream which has a specific additive agent according to desired model shape. While said polyhydric alcohol stream contains the selected additive agents, such as an organic catalyst which controls gelling and bridge construction, a water blowing agent, and a surface-active agent, said additive agent, It collaborates that the shaping total model density, and the smooth model epidermis or surface of cubic feet should be generated every whole about 10-pound cubic feet thru/or 15 pounds of abbreviation.

[0026] In the specific example of this invention, a model compound, By the weight ratio (pbw) of this compound, the amount polyether polyhydric alcohol of polymers of the quantity of about 20 pbw(s) thru/or about 50 pbw(s), Low-molecular-weight polyether polyhydric alcohol of the quantity of about 50 pbw(s) thru/or about 80 pbw(s), The diamine epidermination additive agent of the quantity of about 5 pbw(s) thru/or about 15 pbw(s) which make easy to generate the smooth continuation model surface without a crack, The chain IKUSU tender of the quantity of about 2.5 pbw(s) thru/or about 10 pbw(s), The water blowing agent of the quantity of about 1 pbw thru/or about 4 pbw(s), and the non-silicone surface-active agent of the quantity of about 1 pbw thru/or about 4 pbw(s), each which controls a blowing reaction -- with the amine catalyst of the quantity of the tertiary-amine catalyst of the quantity of about 0.1 pbw(s) thru/or about 1.0 pbw(s), about 0.05 pbw(s), or about 0.2 pbw(s). It grows into bridge construction and the gelling catalyst of the quantity of about 0.015 pbw(s) thru/or about 0.075 pbw(s), diisocyanate of the quantity of about 79.23 pbw(s) which have an isocyanate index of 102 thru/or 105 thru/or about 190.96 pbw(s), and a \*\* real target.

[0027]

[Effect of the Invention] Above so that clearly from detailed explanation in this invention. It is a reaction-injection-molding thermosetting polyurethane foam model which has the same shape as the cast to manufacture, Said smooth reaction-injection-molding thermosetting polyurethane foam model which does not have a surface connection open cell in the lower layer minute network structure of said model and which \*\*\*\*\* and has the model surface is formed, the \*\* which forms a shell mold in the surroundings of said model, and is not accompanied by shell mold cracking -- said model -- from said shell mold -- alternative -- wax -- the molten metal or the melting alloy which comprises heating said shell mold and said model so that omission may be carried out is cast.

Therefore, the process of the shell mold which casts molten metal or a melting alloy by forming

the reaction-injection-molding (RIM) thermosetting polyurethane foam model of low density by the heat collapsibility which has the same shape as the casting to manufacture is provided, the important section of a die with a complicated model -- a duplicate -- every about 10 pounds from which stiffness to the extent that it can surround by investment in a shell mold, without damaging a model, or rigidity is obtained -- cubic feet -- or with the total model density of cubic feet within the limits the whole 15 pounds. The smooth continuation \*\*\*\*\* outside model epidermis or surface which does not have a surface connection open cell in inside of lower layer model minute reticulated core structure, ash-free wax from the stability of the size covering each temperature requirement, and the shell mold which formed the shell mold on the model without carrying out a crack -- it is desirable to be blended so that it may have the removal nature by omission.

There is no organic metal catalyst which must not exist in casting of aerospace superalloy, such as superalloy of nickel \*\* and a cobalt base, in a model. Next, a model is surrounded by investment in a ceramic shell mold or a fireproof shell mold, and the thin film of interface polymer or others is unnecessary on a model.

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[Translation done.]